U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: **FATIGUE AND FAIL-SAFE EVALUATION OF FLIGHT STUCTURE AND PRESSURIZED CABIN FOR PART 23 AIRPLANES**

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1. PURPOSE. This advisory circular (AC) provides information and guidance concerning an acceptable means, but not the only means, of demonstrating compliance with the requirements of part 23 of the Federal Aviation Regulations (FAR) regarding fatigue and fail-safe evaluation of metallic airplane structure. Accordingly, this material is neither mandatory nor regulatory in nature and does not constitute a regulation.

NOTE: This AC was developed from experience with certification of metallic airplane structure; however, much of the material in this AC is applicable to certification of composite structure as well. AC 20-107A, "Composite Aircraft Structure," dated April 25, 1984, contains guidance for certification of composite aircraft structure. The load spectra contained in Report AFS-120-73-2 (refer to paragraph 5a of this AC) should be used without clipping, for composite wing structure of part 23 airplanes.

2. CANCELLATION. Advisory Circular 20-108, "Announcement of Availability--Report No. AFS-120-73-2, Fatigue Evaluation of Wing and Associated Structure on Small Airplanes," dated July 17, 1978, is cancelled.

3. RELATED REGULATIONS. Sections 23.571, 23.572, 23.627, and 23.1529 of the FAR; Special Federal Aviation Regulations (SFAR) 41; and Part 135, appendix A, of the FAR.

4. BACKGROUND. Fatigue evaluation of pressurized cabins was first required for small airplanes by amendment 3-2 of the Civil Air Regulations (CAR), Part 3, effective August 12, 1957, and it continued to be a requirement in the original part 23. Amendment 23-7, effective September 14, 1969, introduced a fatigue requirement for the wing, wing carrythrough, and attaching structure. Amendment 23-34, effective February 17, 1987, added commuter category airplanes to part 23, including an empennage fatigue requirement for these airplanes. SFAR 41 (which applied to part 23 derivative-model airplanes) always had such a requirement. Amendment 23-38, effective

October 26, 1989, added a fatigue requirement to § 23.572 for empennage, canard surfaces, tandem wing, and winglets/tip fins for all part 23 airplanes.

BARRY D. CLEMENTS
Manager, Small Airplane Directorate
Aircraft Certification Service

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1. DEFINITIONS.

a. Fail-safe. Means that the structure has been evaluated to ensure that catastrophic failure is not probable after fatigue failure, or obvious partial failure, of a principal structural element.

b. Safe-life. Means that the structure has been evaluated to be able to withstand the repeated loads of variable magnitude expected during its service life, without detectable cracks.

c. Failure. (See paragraph 2f.)

d. Principal Structural Elements. Those structural elements that contribute significantly to carrying flight, ground*, or pressurization loads, and whose failure could result in catastrophic failure of the airplane.

e. Primary Structure. That structure which carries flight, ground*, or pressurization loads, and whose failure would reduce the structural integrity of the airframe.

f. Single Load Path. Where the applied loads are eventually distributed through a single member, the failure of which would result in the loss of the structural capability to carry the applied loads.

g. Multiple Load Path. Identified with redundant structures in which (with the failure of individual elements) the applied loads would be safely distributed to other load carrying members.

h. Clipping. Limiting the highest fatigue test loads to a level not exceeding limit load, or the load level that is expected to be equalled or exceeded only a small number of times (usually 10 for metallic structure) in the expected life of the fatigue specimen.

i. Reliability. Refers to detail designs or methodologies which analysis, test, and service history has demonstrated to provide acceptable service.

j. Canard or Canard Configuration. An airplane having a horizontal lifting surface (canard surface) forward of the main lifting surface. A canard configuration is one in which the span of the forward lifting surface is substantially less than that of the main lifting surface.

* NOTE: Part 23 fatigue evaluation requirements do not apply to landing gear or fuselage structure (except for pressure cabin); however, ground loads are to be included to the extent that they affect wing, empennage, or canard structure.

k. Tandem Wing Configuration. An airplane having two wings of similar span, mounted in tandem.

l. Forward Wing. The forward lifting surface of a canard or tandem wing configuration airplane. The surface may be a fixed or variable geometry surface, with or without control surfaces.

m. Winglet or Tip Fin. An out-of-plane surface extending from a lifting surface. The surface may or may not have control surfaces.

n. Stabilator. A movable horizontal tail surface combining the function of a horizontal stabilizer and elevator.

2. INTRODUCTION.

a. Deviation from Advisory Circular Procedures. Although a uniform approach to the evaluation required by §§ 23.571 and 23.572 is desirable, it is recognized that in such a complex field, new design features and methods of fabrication, new approaches to the evaluation, and new configurations could necessitate variations and deviations from the procedures described in this AC. Close adherence to the procedures contained in this AC should be encouraged.

b. Test Background. Experience with the application of methods of fatigue evaluation indicates that a test background should exist in order to achieve the design objective.

c. Typical Loading Spectrum Expected in Service. The loading spectrum should be based on measured statistical data of the type derived from government and industry load history studies (e.g., references 10, 11, 12, 13, and 14 in appendix 1) and, where insufficient data are available, on a conservative estimate of the anticipated use of the airplane. The principal loads that should be considered in establishing a loading spectrum are, flight loads (gust and maneuver), ground loads (taxiing, ground handling, engine runup, thrust reversal and landing), ground-air-ground (GAG) cycles, and pressurization loads where applicable. The development of the loading spectrum includes the definition of the expected flight plan, which involves climb, cruise, descent, flight times, operational speeds and altitudes, and the approximate time to be spent in each of the operating regimes. Reference 17 (see appendix 1) contains relevant data on the operating practices of general aviation airplanes. Operations for crew training and other pertinent factors, such as the dynamic stress characteristics of any flexible structure excited by turbulence, should also be considered.

In situations where statistical data are available on similar aircraft configurations, operating comparable flight profiles, it is acceptable to use these data directly without resorting to a flight-by-flight load spectrum definition. For pressurized cabins, the loading spectrum should include the repeated application of the normal operating differential pressure, and the superimposed effects of flight loads and external aerodynamic pressures. In some designs, the wing center section skin panels may be affected by cabin pressurization. In such cases, the effect of cabin pressurization should be included (locally) in the wing loading spectrum.

d. Areas to be Evaluated. In assessing the possibility of serious fatigue failures, the design should be examined to determine probable points of failure in service. In this examination, consideration should be given, as necessary, to the results of stress analyses, static tests, fatigue tests, strain gage surveys, tests of similar structural configurations, and service experience. Service experience has shown that special attention should be focused on the design details of important discontinuities, main attach fittings, tension joints, splices, and cutouts such as access panels and other openings.

e. Analyses and Tests. Unless it is determined from the foregoing examination that the normal operating stresses in specific regions of the structure are of such a low order that serious fatigue crack growth is improbable, repeated load analyses or tests should be conducted on structures representative of components or subcomponents of the pressure cabin, wing, empennage, and their related primary attachments. Care should be taken to account for loads that may be overlooked because of their relatively infrequent occurrence, e.g., landing gear and flap extension and retraction loads. Test specimens should include structure representative of attachment fittings, major joints, changes in section, cutouts, and discontinuities. Any method used in the analyses should be supported, as necessary, by test, service experience, or a combination of both.

f. Definition of Failure. For single load path metallic structure, failure is the development of a detectable crack. A detectable crack is one that can be detected by the inspection method(s) routinely used, or the inspection method(s) required in the maintenance instructions. For multiple load path structure, failure is the development and propagation of cracks, such that the structure can no longer carry the required load without excessive deformation.

3. SAFE-LIFE FATIGUE EVALUATION.

a. General. The evaluation of the structure under the following fatigue strength evaluation methods is intended to ensure that the structure is able to withstand, without catastrophic failure, the repeated loads of variable magnitude expected in service throughout its operational life. Under these methods, loading spectra should be established, the fatigue life of the structure for the spectra should be determined, and a scatter factor should be applied to the fatigue life to establish the safe-life for the structure. This evaluation should include the following; however, occasionally it might be necessary to correlate the loadings used in the analysis with flight load and strain surveys:

(1) Estimating or measuring the expected loading spectra for the structure;

(2) Conducting a structural analysis including consideration of the stress concentration effects;

(3) Fatigue testing of structure that cannot be related to a test background to establish response to the typical loading spectrum expected in service;

(4) Determining reliable replacement times by interpreting the loading history, variable load analyses, fatigue test data, service experience, and fatigue analyses; and

(5) Providing data for inspection and maintenance instructions and guidance information to the operators.

b. Scatter Factor for Safe-life Determination. In the interpretation of fatigue analyses and test data, the effects of variability should, under §§ 23.571 and 23.572, be accounted for by an appropriate scatter factor. Relating test results to the recommended safe-life is extremely difficult since there are considerations peculiar to each design and test that necessitate evaluation by the applicant. These considerations depend on the number of representative test specimens, the material, the type of specimen employed, the type of repeated load test, the load levels, and environmental conditions. Guidance for selecting scatter factors is contained in the report listed in paragraph 5a(1).

c. Replacement Times. Replacement times should be established for parts with established safe-lives, and these should be included in the information prepared under § 23.1529 (discussed in paragraph 3f). These replacement times can be extended if additional data indicates an extension is warranted. Important factors that should be considered for such extensions include, but are not limited to, the following:

(1) Service Experience. Comparison of original evaluation with service experience. Some important factors that should be considered are:

(i) number of airplanes that have been used over an extended life time;

(ii) comparison of the operational and environmental conditions of such airplanes with that of the majority of the existing fleet;

(iii) scatter factor selected for the safe-life determination; and others.

(2) Recorded Load and Stress Data. Recording load and stress data entails instrumenting airplanes in service to obtain a representative sampling of actual loads and stresses experienced. The data to be measured include airspeed, altitude, and load factor versus time; or airspeed, altitude, and strain ranges versus time; or similar data. The data, obtained by instrumenting airplanes in service, provide a basis for correlating the estimated loading spectrum with the actual service experience.

(3) Additional Analyses and Tests. If test data and analyses based on repeated load tests of additional specimens are obtained, a reevaluation of the established safe-life should be made.

(4) Tests of Parts Removed from Service. Repeated load tests of replaced parts can be utilized to reevaluate the established safe-life. The tests should closely simulate service loading conditions. Repeated load testing of parts removed from service is especially useful where recorded load data obtained in service are available, since the actual loading experienced by the part prior to replacement is known.

(5) Repair or Rework of the Structure. In some cases, repair or rework of the structure can gain further life; e.g., by reaming or cold working of holes and installation of interference fit fasteners. Such repair or rework should be supported by analysis and/or tests.

d. Type Design Developments and Changes. For design developments or design changes involving structural configurations similar to those of a design already shown to comply with the applicable provisions of § 23.572(a), it might be possible to evaluate the variations in critical portions of the structure on a comparative basis. Typical examples would be, redesign of the wing or empennage structure for increased loads. This evaluation should involve analysis of the predicted stresses of the redesigned primary structure and correlation of the analysis with the analytical and test results used in showing compliance of the original design.

e. Environmental effects such as temperature and humidity should be considered in the fatigue and fail-safe evaluation if susceptible materials are employed, or the expected service environment may cause corrosion, pitting, etc., which would reduce the predicted fatigue life.

f. Continued Airworthiness.

(1) Instructions for Continued Airworthiness are required by § 23.1529, and they are to be prepared in accordance with appendix G of part 23. Paragraph G23.4 requires that each mandatory replacement time, structural inspection interval, and related structural inspection procedure required for type certification be in the Airworthiness Limitations Section of the Instructions for Continued Airworthiness. Therefore, any life limits on airframe parts or

inspections required, including information such as required clamping torques, protective coatings, etc., determined from the fatigue or fail-safe evaluation, must be provided in the above-mentioned document.

(2) Severe usage operation is characterized by short flight duration, frequent maneuvering, or unusually low altitude operation, e.g., commuter airline service, air taxi, basic flight instruction, aerial application, pipeline patrol, forest fire fighting, navigation aids inspection, etc. If severe usage operation is anticipated where the gust or maneuver load spectrum is more severe, or if flight duration is significantly shorter than that used in the fatigue testing and analysis, additional inspections or reduced inspection intervals should be included in the Airworthiness Limitations Section of the Instructions for Continued Airworthiness, for application when the airplane is employed in such operations.

4. FAIL-SAFE EVALUATION.

a. General. The fail-safe strength evaluation of the flight structure and pressure cabin structure is intended to ensure that should a service fatigue failure or obvious partial failure occur, the remaining structure can withstand the pressurization and flight loads required by §§ 23.571 and 23.572, without excessive structural deformation. The fail-safe evaluation generally encompasses establishing the components that are to be made fail-safe, defining the loading conditions and extent of damage for which the structure is to be designed, conducting structural tests and analyses to substantiate that the design objective has been achieved, and establishing inspection programs aimed at early detection of fatigue damage. Design features that may be used in attaining a fail-safe structure are:

(1) Use of multipath construction and the provision of crack stoppers to limit the growth of cracks.

(2) Use of composite (i.e., more than one element) duplicate structures so that a fatigue failure occurring in one-half of the composite member will be confined to the failed half and the remaining structure will still possess the load-carrying ability required by §§ 23.571 and 23.572.

(3) Use of backup structure wherein one member carries all of the load, with a second member available that can assume the extra load if the primary member fails.

(4) Selection of stress levels and materials with low notch sensitivity (particularly for components with high stress concentration) that provide a controlled slow rate of crack propagation combined with high residual strength after initiation of cracks.

(5) Arrangement of design details to permit easy detection of failures in all critical structural elements before the failures can become dangerous or result in a loss of strength below that required by §§ 23.571 and 23.572, and to permit replacement or repair.

NOTE: Subparagraphs 4a(4) and (5) are examples of good design practice and enhance fail-safe design concepts, but they cannot be used alone to achieve fail-safe design.

b. Identification of Principal Structural Elements. Principal structural elements are those structural elements that contribute significantly to carrying flight, ground*, or cabin pressurization loads, and whose failure could result in catastrophic failure of the airplane. Typical examples of such elements are as follows:

(1) Wing, horizontal stabilizer, vertical fin, canard, forward wing, winglets/tip fins:

(i) Fixed surface, stabilator, or trimmable stabilizer attachment fittings;

(ii) Integrally stiffened plates;

(iii) Primary fittings;

(iv) Principal splices;

(v) Skin or reinforcement around cutouts or discontinuities;

(vi) Skin-stringer combinations;

(vii) Spar caps; and

(viii) Spar webs.

(2) Pressurized cabin.

(i) Circumferential frames and adjacent skin;

(ii) Pressure bulkheads;

(iii) Cockpit window posts;

(iv) Skin and any single frame or stiffener element around a cutout;

* NOTE: Part 23 fatigue evaluation requirements do not apply to landing gear or fuselage structure (except for pressure cabin); however, ground loads are to be included to the extent that they affect wing, empennage, or canard structure.

(v) Skin or skin splices, or both, under circumferential loads;

(vi) Skin or skin splices, or both, under fore and aft loads;

(vii) Skin around a cutout;

(viii) Skin and stiffener combinations under fore and aft loads;

(ix) Door frames, skins, and latches; and

(x) Window frames.

c. Extent of Fail-safe Damage. Each particular design should be carefully assessed to establish appropriate damage criteria. In any fatigue damage determination, when it is not possible to establish the extent of damage in terms of an "obvious partial failure," the damage should be considered in terms of the complete failure of the single element involved. Thus, an obvious partial failure can be considered to be the extent of the fail-safe damage, provided a positive determination is made that the fatigue cracks are expected to propagate in the open; for example, exterior skin cracks that can be detected by a visual inspection at an early stage of the crack development. Another example of an obvious partial failure is excessive cabin pressure leaks as evidenced by the inability to maintain cabin operating pressure. Typical examples of the fatigue damage that should be considered are outlined below:

(1) Skin cracks in splice joints and those emanating from the edge of structural openings or cutouts that can be readily detected by visual inspection of the area.

(2) Failure of one element where dual construction is used in components such as spar caps, window posts, window or door frames, and skin structure.

(3) The presence of a fatigue failure in at least the tension portion of the spar web or similar elements.

(4) Failure of one element of primary attachments, such as: wing and empennage fixed surface or stabilator attach fittings.

(5) Excessive loss of stiffness under load as evidenced by excessive deformation.

d. Inaccessible Areas. Every reasonable effort should be made to ensure inspectability of all principal structural elements as required by § 23.611. In cases where inaccessible or blind areas are unavoidable, emphasis should be placed on determining crack propagation and residual strength of the particular fatigue-damaged structure, to ensure continued airworthiness of the structure with reasonable inspection methods and controls by the operator. Alternate procedures would be to provide additional fatigue strength to preclude fatigue cracking in the blind element or to conduct fatigue tests of the blind areas to establish that a high service life is provided. Particular attention should be given to corrosion prevention in inaccessible areas.

e. Dynamic Effects. The dynamic magnification factor of 1.15, required by §§ 23.571 and 23.572, should be applied to all loads, including pressure cabin loads, unless fail-safe cuts are made under load, or the dynamic effects are shown to be negligible by dynamic test data from a similar structure.

f. Testing of Principal Structural Elements. The nature and extent of tests on complete structure and/or portions of the primary structure will depend upon previous experience with similar types of structures regarding tests of this nature and the crack propagation characteristics of the structure. Single elements or members such as stringers and spar caps should be completely severed and 1.15 times the critical fail-safe load applied after severing. In cases where definite evidence is furnished that the dynamic failure effects are not present, the 1.15 factor may be eliminated or reduced in accordance with the effects noted. Sections 23.571 and 23.572 require that the remaining structure can withstand a static ultimate load factor of 75 percent of the critical limit load factor at V_C.

Alternatively, the fail-safe loads may be applied to the structure before severing, and the 1.15 factor omitted. In this case, the test specimen and test fixture must be carefully designed to ensure that the correct dynamic effects are obtained. In the case of distributed members such as a sheet-stringer combination or an integrally stiffened tension skin, a cut may be made to represent an initial crack in the element under test. If there is no failure, the length of the cut may be increased with the fail-safe load applied until either:

(1) The fail-safe damage has been simulated; or

(2) The crack propagation rate decreases due to redistribution of load paths; or

(3) Crack propagation stops due to a crack stopper.

The simulated cracks should be as representative as possible of actual fatigue damage. In cases where it is not practical to produce actual fatigue cracks, damage may be simulated by cuts made with a fine saw, sharp blades, or a guillotine. If sawcuts in primary structure are used to simulate sharp fatigue cracks, sufficient evidence should be available from element tests to indicate equivalent residual strength. In those cases where it is necessary to simulate damage at joints or fittings, bolts may be removed to simulate the failure if this condition represents an actual failure.

g. Analysis of Principal Structural Elements. In some cases, the fail-safe characteristics may be shown analytically. The analytical approach may be used when the structural configuration involved is essentially similar to one already verified by fail-safe tests, whether conducted on a previously approved type design or on other similar areas of the design currently being evaluated.

The analytical approach may also be used when conservative failures are assumed such that the failure would be detected considerably before the critical crack length is approached, and margins of safety resulting from the analysis are considerably more than the fail-safe residual static strength level. In any such analysis, the 1.15 dynamic magnification factor should be included unless it can be shown (as indicated in paragraph 4e above) that this factor is not required.

h. Selection of Critical Areas. Typical single principal structural elements and detail design points requiring investigation are identified under paragraph 4b. The process of determining where fail-safe damage should be simulated in an element, such as a wing spar cap or fuselage frame, requires use of sound engineering judgment that takes into account a variety of factors, such as:

(1) Conducting an analysis to locate areas of maximum stress and low margin of safety.

(2) Conducting strain gage surveys on undamaged structure to establish points of high stress concentration as well as the magnitude of such concentration.

(3) Examining static test results to determine locations where excessive deformations occurred.

(4) Determining from repeated load tests where failure may have initiated or where the crack propagation rate is a maximum.

(5) Selecting locations in an element (such as a spar cap) where the stresses in adjacent elements (such as the spar web or wing skin) would be the maximum with the spar cap failed.

(6) Selecting points in an element (such as a spar web or frame) in which high stress concentrations are present in the residual structure with the web failed.

(7) Assessing detail design areas that service experience records of similarly designed components indicate are prone to fatigue damage.

(8) Areas susceptible to operational damage, such as: foreign object damage, corrosion, etc.

i. Inspection. Detection of fatigue cracks before they become dangerous is the ultimate control in ensuring the fail-safe characteristics of flight structure and pressurized cabin. Therefore, the aircraft manufacturer should provide sufficient guidance information to assist operators in establishing the frequency and extent of the repeated inspections of the critical structure or critical areas.

Where these inspections involve more than a general visual inspection of external and easy access areas, then frequency and extent are to be included in the information prepared under § 23.1529 (discussed in paragraph 3f).

5. ANALYSIS PROCEDURES.

a. Load Spectra. Examples of typical fatigue analysis, load spectra, and recommended procedures for developing load spectra are presented in the following FAA reports:

(1) FAA Report No. AFS-120-73-2: "Fatigue Evaluation of Wing and Associated Structure on Small Airplanes," May 1973.

(2) FAA Report: "Fatigue Evaluation of Empennage, Forward Wing and Winglets/Tip Fins on Part 23 Airplanes."

(3) Report DOT-FAA-CT-91-20, "General Aviation Airplane Normal Acceleration Data Analysis and Collection Program," December 1992 (reference 12 in appendix 1).

References 13 and 14 listed in appendix 1 also contain recorded load spectra.

Availability: (1) The first report above may be ordered (Accession No. AD 762832) from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161 (telephone number: (703) 487-4650). (2) The second report above is expected to be published and be available from NTIS later in 1993. (3) The third report is expected to be available from NTIS shortly after publication of this AC.

b. Mutual Influence of Aerodynamic Surfaces. The total aerodynamic loads on the wing and tail surfaces of a conventional airplane can be predicted with reasonable accuracy using geometry, airfoil section data, and empirical equations to account for wing downwash effects. Furthermore, the total surface aerodynamic loads can be distributed spanwise simply, and with reasonable accuracy. Until sufficient data have been generated to be able to develop simplified methods, some form of lifting surface or full configuration aerodynamic theory is recommended to evaluate the effects of the forward wing and any out-of-plane surfaces such as winglets. Typical procedures are discussed in reference 18.

Many analysis techniques are already available commercially, and others are under development. A comparison of several production codes is presented in reference 19.

c. Propeller Slipstream and Buffet Loading. Structural loading resulting from propeller slipstream, or buffet from vortex impingement should be evaluated, specifically, if structural vibration modes are excited by propeller blade passage frequencies. If significant, these loads should be included in the load spectrum. Since there are no reliable analytical techniques available to evaluate these effects, flight test measurements should be used.

APPENDIX 1

RELATED READING MATERIAL AND REFERENCES

1. "Fatigue of Aircraft Structures," H. J. Grover, Battelle Memorial Institute. NAVAIR Publication 01-1A-13, Naval Air Systems Command, Department of the Navy, 1966.

2. "Fatigue and Fracture Mechanics," H. F. Hardrath, NASA Langley Research Center. Journal of Aircraft, Volume 8, Numberá3, American Institute of Aeronautics and Astronautics, March 1971.

3. "Fatigue of Aircraft Structures," J. Schijve, Department of Aerospace Engineering, Delft University of Technology, Netherlands, April 1986. Available from the National Technical Information Service (NTIS), accession number N87-27656 (refer to paragraph 5a for ordering information).

4. Chapter 15 in "Airframe Structural Design," M.C.Y. Niu, Lockheed Aeronautical Systems Company. Comlit Press Ltd., 1988.

5. "Metal Fatigue: Theory and Design," A. F. Madayag (Editor), University of Southern California at Los Angeles. John Wiley & Sons, Inc., New York, 1969.

6. Chapter C13 in "Analysis & Design of Flight Vehicle Structures," E. F. Bruhn, Purdue University. Tri-State Offset Company, Cincinnati, Ohio, 1965.

7. "Fatigue in Aircraft Structures" A. M. Freudenthal (Editor), Columbia University. Academic Press, Inc., New York, 1956.

8. ASTM Standard E1150, "Standard Definitions of Terms Relating to Fatigue," American Society for Testing and Materials, Philadelphia, Pennsylvania, 1987.

9. ASTM Special Technical Publication No. 91-A, "A Guide for Fatigue Testing and the Statistical Analysis of Fatigue Data," American Society of Testing and Materials, Philadelphia, Pennsylvania, 1963.

10. FAA Report No. AFS-120-73-2, "Fatigue Evaluation of Wing and Associated Structure on Small Airplanes," Federal Aviation Administration, Washington, D.C., 1973.*

11. FAA Report, "Fatigue Evaluation of Empennage, Forward Wing and Winglets/Tip Fins on Part 23 Airplanes," Federal Aviation Administration, Kansas City, Missouri.*

* NOTE: Refer to par. 5a of this AC for ordering information and availability.

12. Report DOT-FAA-CT-91-20, "General Aviation Airplane Normal Acceleration Data Analysis and Collection Program," E. A. Gabriel and T. DeFiore, FAA; J. E. Locke and H. W. Smith, University of Kansas Center for Research, Inc. Federal Aviation Administration, Washington D.C., December 1992.*

13. NASA Technical Memorandum 84660, "Tabulation of Recorded Gust and Maneuver Accelerations and Derived Gust Velocities for Airplanes in the NASA VGH General Aviation Program," J. W. Jewel, Jr., Langley Research Center, Hampton, Virginia, September 1983.

14. Engineering Sciences Data Unit (ESDU) Item 69023, "Average Gust Frequencies, Subsonic Transport Aircraft," with Amendments A through C (1979), Amendment D (March 1989).**

15. Engineering Sciences Data Unit (ESDU) Item 80007, "Endurance of Aluminum Alloy Lugs with Nominally Push-fit Pins (tensile mean stress)," with Amendment A, September 1984.**

16. Engineering Sciences Data Unit (ESDU) Item 79024, "Estimation of Endurance of Civil Aircraft Wing Structures," October 1979.**

17. NASA Technical Memorandum 89074, "Flight Duration, Airspeed Practices, and Altitude Management of Airplanes Involved in the NASA VGH General Aviation Program," J. W. Jewel, Jr., Langley Research Center, Hampton, Virginia, August 1987.

18. AIAA paper 88-4462, "Canard Certification Loads - Progress Toward Alleviating FAA Concerns," T. J. Barnes and E. A. Gabriel, Federal Aviation Administration. Published by American Institute of Aeronautics and Astronautics, September 1988.

19. AIAA paper 85-0280, "Subsonic Panel Methods - A Comparison of Several Production Codes," R. J. Margason; S. O. Kjelgaard; W. L. Sellers, III; C. E. K. Morris, Jr., NASA Langley Research Center, Hampton, VA; K. B. Walkly; E. W. Shields, Kentron International, Inc. Published by American Institute of Aeronautics and Astronautics, 1985.

20. FAA Advisory Circular No. 20-95, "Fatigue Evaluation of Rotorcraft Structure," Federal Aviation Administration, Washington, D.C., 1976.

<u>NOTES</u>: *Refer to par. 5a of this AC for availability.

**Available from ESDU International, P.O. Box 1633, Manassas, Virginia, 22110. Telephone: (703) 631-4187.